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Road Condition Detection Techniques: A Comparative Analysis based on Supervised Machine Learning Techniques

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***Abstract*—With the advancement in autonomous vehicle and use of intelligent transportation system, road accidents are also increasing at higher rate. Road safety becomes a one of the major concerns for the transportation system and government. Road accident and road death are gaining highest percentage ration in number of deaths. Potholes, road bumps and slippery roads are the prime reason for the road accident. To take the prevention against road accident many technology-based solutions were provided by the research community. These solutions are based on machine learning techniques and smart phone-based technologies. In this paper, machine learning techniques were used to predict the road conditions. Kaggle data set of the road condition is considered for the experiment. Accuracy of Random Forest, Decision Tree, K Neighbors, Naïve Bayesian, Suport Vector Machine and Multi-layer Perceptron Classifier is compared using the vibration dataset of road network. Maximum accuracy of 91.8 percent and F1 score of 97 percent was achieved by the random forest classifier. Whereas minimum accuracy value 25 percent was achieved by the Complement Naïve Bayesian Classifier. Accuracy, F1 score, Recall, Precision and other calculated results can be used by the intelligent transport system to generate the alert to driver about the road condition and further these algorithms can be used by the road authority to identify the road conditions and then to take corrective action like road repair and maintenance.**

***Index Terms*— Support Vector Machine, Pothole, Bayesian Classifier, Bumps.**

I. INTRODUCTION

With the advancement in transport technologies, vehicles are becoming more autonomous and number of vehicles are also increasing. The increase in the count of vehicle also causing large number of road accidents. In India, 449,002 road accidents were reported in year 2019 and out of these accidents 151,113 deaths took placed. Road Condition, Human Error, Vehicle condition and Environmental Conditions are the major factors for the road accidents. According to reports, in 2018 and 2019, 47 percent road accident in open area were caused by the road conditions. In last 5 years, on an average 16 percent accidents (including all type of road areas) were due to the road conditions [1], [2]. Road Accident are highly dependent on road conditions and there is close relationship between road accident and potholes/ humps. Large potholes and bad road conditions leads to high traffic on roads and also creates many problems for the travelers and vehicles. So as to avoid these scenarios, few systems has been developed that provide the details of the road to road authorites so that proper action can be taken. Apart for it, these systems are also capable to share the road information to driver so that they can plan

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their route accordingly. Many road condition monitoring techniques has been proposed by the research community using the stereo camera, sensors, mobile phone, etc. [3], [4].

Number of humps and potholes describes the condition of road. Existence of pothole in road means road condition is not good. These potholes are responsible for the high traffic and congestion, high fuel consumption, bad driving style, irritating driving style and more road accident. Many methods exists to identify the potholes and these methods are categorized into three part term as; vision based, 3D reconstruction based and vibration based methods [5]. Vision based methods uses camera images and videos to identify the potholes in the road. 3D reconstruction-based method uses stereo methods, laser techniques and Kinect sensor for the bump's detections. Vibration based method uses reading of the accelerometer, gyroscope or other sensors of the device. These method records the jumps and vibration of the moving device [6]–[8] . During the initial stage of vision-based techniques, special devices were designed and created using the vision-based devices and computers. These devices used to capture the images of the road and after data collection these images were used for the analysis. With advancement of technology, portable and small monitoring devices were used as a replacement of specially designed heavy devices for the data collection and analysis. After the evolution of mobile cameras, data collection became much easier for the vision-based techniques. Mobile devices act as source of data collection and then neural network and machine learning techniques were being used for the road monitoring and predictions. For vision-based techniques large storage space is required. In addition to space the good image clarity and depth information of pothole is also required [9], [10].

Due to advanced technologies and powerful features of smart phones, smart phones have replaced computers for many activities. Now a day smart phones are being used for data collection, data processing, data conversion and for many other activities. Many studies also used smart phones for the pothole detection and data collection for the road conditions and potholes. Smart phones-based pothole detection techniques are of two type; termed as threshold based and machine learning based. Sensor data of the device is used to identify the vertical movement of the device and this vertical movement can be retrieved from the Z axis reading of the device [11]. Different supervised and unsupervised machine learning algorithms like Support Vector Machine (SVM), Decision Tree, K-Means, Random Forest, Dynamic Time Wrapping (DTW), CNN, Multi-Layer Perceptron (MLP) etc., were used to detect the potholes, bumps, manholes, cracks and rough roads [12]–[15]. Smart phone-based techniques can detect the road anomalies with less resources and with good accuracy. As per the studied literature, few of the combined advantages and disadvantages of smart phone-based road anomalies detection techniques are presented in TableI.

This paper presents an experiment performed to detect the pothole using the sensor dataset. Dataset was captured using the mobile device and data was processed using different machine learning techniques. Random Forest Classifier, Decision Tree Classifier, K Neighbors Classifier, Multinomial Naïve Bayesian (NB), Complement NB, Bernoulli NB, SVM, Linear SVM, and MLP Classifier were considered for the experiment. At the end, an analysis was performed to check the performance and accuracy of machine learning techniques on road dataset.

II. METHODOLOGY

This paper provides the road anomaly detection techniques using machine learning algorithms. For road anomalies and potholes detection a Kaggle dataset was considered in this experiment. Engine reading and sensor readings are the part of this data. In general, the pothole detection techniques using smart phone comprises 5 basic steps, these steps are shown in figure2. The first step is to collect the data using smart phone sensor. For

Advantages	Disadvantages	Reference
• Simple Structure • Less resource Requirement • Fast processing • Efficient in their category • Les power consumption • Easy implementation • Works in real time scenario • No need to have special hardware and software setup • Easy to work with GPS and location aware scenario • Better mapping with road and potholes • Easy for data set collection	• Suffers from accelerometer calibration issues • Orientation and position of smart phone plays important role and also effect the accuracy • Poor accuracy in case of large number of potholes in small region • Sensitive to false positive data • Accuracy is also affected by the vehicle speed and type • Environmental conditions also have impact on accuracy	[5], [12], [16]–[21]

the data collection process, smart phone is placed at stable position and then reading of accelerometer is used to check the vibrations of the device. Vertical movement of the device is captured using the Z axis of the dataset. The capture data may contain some errors, duplicate entries and null values so in the next step data is prepressed. In this preprocessing step, data is cleansed and false positive and true negative values are also filter out. This filtered data is used to train and test the machine learning model. Based on the dataset, the real time smart phone-based pothole detection system monitors the road condition, performed certain analysis and based on this system generates alarm or alert to user.

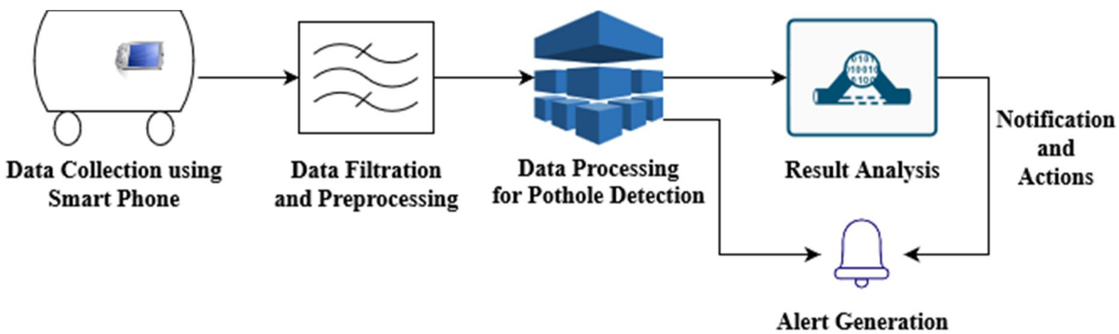

Figure 1 General Steps for the Road Condition Detection Techniques

For this experiment, the first two steps of the figure 2 are not performed because in this experiment Kaggle dataset was used. This data is now processed using different machine learning algorithms. Accuracy is detected for each algorithm and then result analysis performed to check the performance of different algorithms on same dataset. Alarm generation step is also not the part of this experiment as the experiment is only for the purpose of analysis. In this experiment Random Forest Classifier, Decision Tree Classifier, K Neighbors Classifier, Naïve Bayesian classifier, SVM and Multi-layer Perceptron classifier were considered. In NB Classifier, three different model names as Multinomial NB, Complement NB, Bernoulli NB are used. Similarly, both SVM and Linear SVM model were considered for the experiment.

III. Result Analysis

To perform the experiment, Scikit learn library was used. The considered dataset contains 24957 entries and each entry had 14 different values. The field of the dataset were Vehicle Speed Instantaneous, Vehicle Speed Average, Vehicle Speed Variance, Vehicle Speed Variation, Longitudinal Acceleration, Engine Load, Engine Coolant Temperature, Manifold Absolute Pressure, Engine RPM, Mass Air Flow, Intake Air Temperature, Vertical Acceleration, Fuel Consumption Average. Training and Testing data was spitted int0 80:20. 80 percent data considered for the training and 20 percent data considered for the testing. Accuracy of the all models were tested using below mentioned matrices.

Accuracy Score: It measure the matching of predicted labels with actual label. Higher value of accuracy means better classification.

Zero-one loss: It measure the count of wrong classification or misleading classification

Hamming Loss: It counts the wrong prediction of labels.

Jaccard Score: Analyze the correct mapping of label with true score

F1 Score: F1 score can be calculated using precision and recall values. It measures the classification accuracy of the model

F1 Score = 2 * (precision * recall) / (precision + recall)

Table I. shows the analysis of considered machine learning models with respect to accuracy, Zero-one loss, Hamming loss and Jaccard Score.

Algorithm	Accuracy	Zero One Loss	Hamming loss	Jaccard Score
Random Forest Classifier	0.91	0.08	0.02	0.96
Decision Tree Classifier	0.84	0.16	0.03	0.93
K Neighbors Classifier	0.89	0.11	0.03	0.93
Multinomial NB	0.46	0.52	0.18	0.66
Complement NB	0.25	0.73	0.4	0.46
Bernoulli NB	0.46	0.52	0.18	0.66
SVM	0.58	0.42	0.11	0.77
Linear SVM	0.49	0.5	0.15	0.7
MLP Classifier	0.46	0.52	0.18	0.66

Algorithm	F1 Score	Recall	Precision
Random Forest Classifier	0.97	0.96	0.97
Decision Tree Classifier	0.95	0.95	0.95
K Neighbors Classifier	0.95	0.95	0.95
Multinomial NB	0.64	0.74	0.57
Complement NB	0.59	0.59	0.71
Bernoulli NB	0.64	0.74	0.7
SVM	0.81	0.81	0.87
Linear SVM	0.73	0.75	0.76
MLP Classifier	0.64	0.74	0.57

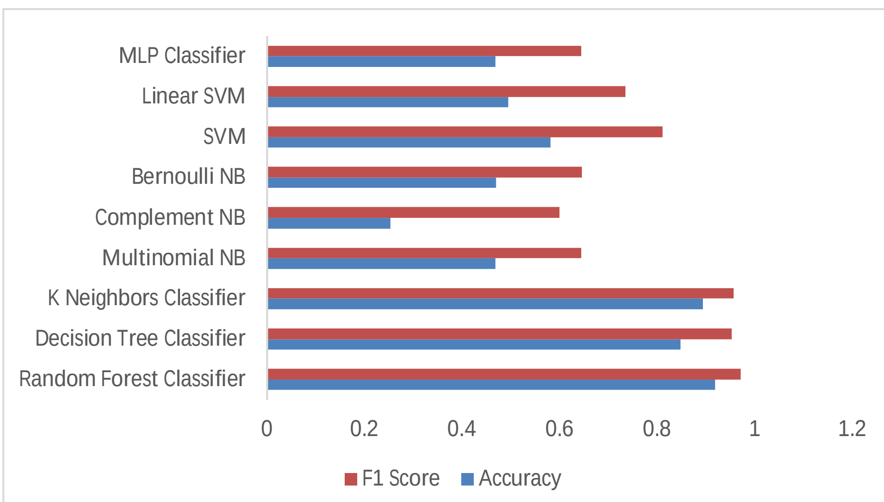

Figure 2 Accuracy and F1 score-based comparison of considered techniques using pothole dataset

IV. Conclusion

Road conditions play important role for intelligent transport system. Bad road conditions are responsible for major accidents and deaths. Many research studies have been done to detect and monitor the road conditions. In this paper, sensor-based data set was considered to predict the road condition and to identify the presence of potholes using machine learning techniques. An experiment was conducted using Random Forest Classifier, Decision Tree Classifier, K Neighbors Classifier, Naïve Bayesian classifier, SVM and Multi-layer Perceptron classifier. These considered machine learning techniques were implemented on same dataset. Accuracy to predict the pothole by each considered algorithm was determine using the accuracy, recall, precision, F1 score, and Jaccard score. Further prediction error rate is identified using the hamming loss and zero-one loss factor. From the result analysis it has been observed that random forest classifier has highest accuracy (91 percent) and Complement NB (025 percent) has lowest accuracy of pothole prediction among the considered algorithm. This analysis can be further use to select the appropriate algorithm for the pothole detection. In real time application situation, algorithm with best accuracy and lower error rate can be use to generate the alert about the road conditions.

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